Optimizing MRI Detection of Recurrence in Head and Neck Cancer: The Clinical Impact of NI-RADS Post-Treatment

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Abstract

Background: Head and neck squamous cell carcinoma (HNSCC) are associated with high recurrence rates, necessitating effective post-treatment surveillance to improve patient outcomes.

Objectives: This study evaluates the role of Neck Imaging Reporting and Data System (NI-RADS) Scores in predicting disease recurrence in patients with HNSCC.

Patients and methods: This retrospective cohort study included patients diagnosed with HNSCC. Demographic, clinical, and treatment-related data were collected, with MRI findings and NI-RADS scores used to assess recurrence. MRI findings such as T1- and T2-weighted imaging and diffusion-weighted imaging (DWI) and contrast study were analyzed for their role in detecting residual or recurrent disease.

Results: The study involved 120 patients with treated head and neck cancer, with an average age of 59 years, predominantly male (80.8%). The most common primary tumor sites were the larynx, oral cavity, and hypopharynx. Tumor stages ranged from I-IV, with 30% at stage II and 55% being moderate grade. NI-RADS scores showed 41.7% classified as NI-RADS 1 and 30.8% as higher-risk NI-RADS 3. Treatment included chemotherapy, surgery, and combinations, with 31.7% receiving both chemotherapy and radiotherapy. And MRI findings correlated with NI-RADS classifications, showing higher recurrence rates for higher NI-RADS categories, especially NI-RADS 2b, 3, and 4, with statistically significant differences ($p < 0.001$).

Conclusion: Higher NI-RADS scores were associated with higher recurrence rates, particularly in primary sites and lymph nodes. NI-RADS MRI serves as a reliable tool for risk stratification and decision-making in post-treatment surveillance.

Keywords: Head and neck squamous cell carcinoma (HNSCC); MRI; NI-RADS; Recurrence; Diffusion-weighted imaging (DWI).

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Introduction

Head and neck squamous cell carcinoma (HNSCC) is a significant global health concern, accounting for approximately 4% of all cancers worldwide **(Cowie and Fisher, 2020)**. Despite advancements in treatment modalities, including surgery, radiotherapy, and chemotherapy, the recurrence rate for HNSCC remains alarmingly high, ranging between 20% and 50% depending on the initial stage of the disease and treatment approach **(Miyamaru et al., 2023)**. Early detection of recurrence is critical as it offers the best chance for effective salvage treatment and improved survival outcomes. However, accurately predicting recurrence post-treatment remains a challenge in clinical practice due to complex anatomical changes caused by therapeutic interventions, such as fibrosis and tissue distortion, which may obscure early signs of tumor regrowth **(Junn et al., 2021)**.

In recent years, imaging modalities, particularly magnetic resonance imaging (MRI), have been increasingly utilized in the surveillance of patients with treated head and neck cancers. Although MRI offers superior soft tissue resolution, it is less valuable in detecting subtle changes indicative of tumor recurrence **(Junn et al., 2021)**. However, the interpretation of post-treatment imaging can be challenging due to the aforementioned anatomical changes, and there is a need for standardized reporting systems to guide radiologists and clinicians in identifying potential recurrences **(Abdelaziz et al., 2020)**. The Neck Imaging Reporting and Data System (NI-RADS) is an emerging standardized reporting system developed to assess and categorize post-treatment imaging findings in patients with HNSCC **(Wangaryattawanich et al., 2018)**. Despite its growing adoption, the application of NI-RADS to MRI is still relatively new and underexplored in the literature **(Elsholtz et al., 2021)**.

Thus, exploring the predictive value of NI-RADS in MRI for recurrent head and neck carcinoma after treatment could provide significant insights into optimizing patient outcomes.

The aim of this study was to evaluate the effectiveness of NI-RADS MRI in predicting the recurrence of head and neck carcinoma after treatment.

Patients and methods

The retrospective study was conducted on a cohort of 120 patients aged 18 years or older with histologically confirmed HNSCC who had completed definitive treatment, including surgery, radiotherapy, and/or chemotherapy who underwent MRI study between November 2021 and August 2023. Patients were eligible for inclusion if they had undergone contrast-enhanced MRI within 6 months post-treatment and had a NI-RADS score documented for surveillance purposes. All patients were followed for up to 12 months to confirm the presence or absence of disease recurrence.

Exclusion criteria included patients with non-squamous cell carcinoma, those whose primary tumors were located outside the head and neck region, and those with incomplete follow-up data or contraindications to MRI (e.g., pacemakers, severe claustrophobia).

Informed consent was obtained from all patients or their legal representatives, ensuring they understood the study's benefits, purpose, and methodology. The study, approved with ethical code 36264PR832/8/24.

Imaging Protocol

MRI scans were performed on a 1.5 Tesla system (GE signa explorer), using a standardized protocol for post-treatment surveillance. The sequences included in the protocol were:

The T1-weighted (T1W) images were acquired in axial, coronal, and sagittal planes to offer a detailed evaluation of anatomical structures and tumor margins. Typical parameters for this sequence included a repetition time (TR)

of 400–800 ms and an echo time (TE) of 10–20 ms. Slice thickness was maintained at 4–5 mm, with a field of view (FOV) ranging from 220 to 260 mm, and a matrix size of 256 × 192. The acquisition time for T1W images was approximately 2 to 4 minutes.

The T2-weighted (T2W) images were employed to assess tumor-related edema, residual soft tissue changes, and possible tumor recurrence. These scans used a TR of 2000–4000 ms and a TE of 80–120 ms, with the same slice thickness of 4–5 mm. The FOV was kept between 220 and 260 mm, and the matrix size was increased to 320 × 224 for higher spatial resolution. The acquisition time typically ranged from 3 to 5 minutes.

Short Tau Inversion Recovery (STIR) sequences were included to distinguish post-treatment changes, such as scarring and edema, from active disease, especially in soft tissues. This fat-suppressed sequence used a TR of 3000–5000 ms, a TE of 60–80 ms, and an inversion time (TI) of 150–200 ms. Slice thickness was adjusted to 4–6 mm, with a FOV of 240–280 mm and a matrix size of 256 × 192. The acquisition time for the STIR sequence was around 4 to 6 minutes.

Diffusion-Weighted Imaging (DWI) assessed the diffusion of water molecules within tissues, helping to identify suspicious areas with restricted diffusion. Low apparent diffusion coefficient (ADC) values were considered concerning tumor recurrence. DWI was performed with a TR of 4000–7000 ms and a TE of 70–90 ms. Slice thickness was kept at 4–5 mm, with a FOV between 240 and 280 mm. The matrix size was set to either 128 × 128 or 192 × 192, and b-values of 0, 800, and 1000 s/mm² were used. This sequence required around 2 to 3 minutes for completion.

Contrast-enhanced MRI was performed using gadopentetate dimeglumine as the contrast agent, administered intravenously at 0.1 mmol/kg body weight. Both pre-contrast and post-contrast T1-weighted images were obtained to compare enhancement patterns and assign a NI-RADS category based on NI-RADS™ MRI Category Descriptors, Imaging Findings, and Management **(Dinkelborg et al., 2021)**.

Data Collection

Patient demographic and clinical data, including age, gender, tumor stage, treatment modality, and initial pathology, were collected from medical records. The NI-RADS scores from post-treatment MRI scans were documented, and subsequent clinical outcomes were evaluated. Recurrence was confirmed by histopathological analysis from biopsy or subsequent imaging findings.

In addition to recurrence data, renal function was assessed in patients receiving gadolinium-based contrast agents. Serum creatinine and estimated glomerular filtration rate (eGFR) were monitored pre- and post-contrast to evaluate any potential impact of gadolinium on kidney function. Patients with an eGFR below 60 mL/min/1.73 m² were closely monitored, and no significant contrast-induced nephropathy was observed during the study period.

Statistical Analysis

SPSS version 27.0 was used for data management and analysis. Quantitative data were described using mean ± standard deviation (SD) when appropriate, while qualitative data were presented as numbers and percentages. Binary logistic regression analysis was employed to identify factors that could predict recurrence of carcinoma among the study participants. A p-value of less than 0.05 was considered statistically significant. All statistical tests were two-tailed to ensure the robustness of the results.

Results

The study included 120 patients with treated head and neck cancer. The average age of the participants was 59 years (± 23) and ranged from 43 to 67 years, with a majority being male (80.8%). The most common primary tumor site was the larynx

(29.2%), followed by the oral cavity (21.7%), hypopharynx (17.5%), nasopharynx (16.7%), and oropharynx (15%). At diagnosis, tumor stages were distributed across stages I-IV, with 30% of patients diagnosed at stage II, and the majority (55%) of tumors being moderate grade. NI-RADS scores for the primary site showed that 41.7% were classified as NI-RADS 1, while 30.8% were in the higher-risk category, NI-RADS 3. The distribution for lymph nodes also revealed that the majority (70%) were NI-RADS 1 **(Table.1).**

Table 1. Demographic and clinical characteristics of studied patients

Study Group Characteristics (N=120)	Category	n (%)
Age	Mean ± SD	59 ± 23
	Range	43 - 67
Gender	Female	23 (19.2%)
	Male	97 (80.8%)
Primary Site of Tumor	Hypopharynx	21 (17.5%)
	Larynx	35 (29.2%)
	Nasopharynx	20 (16.7%)
	Oral cavity	26 (21.7%)
	Oropharynx	18 (15.0%)
TNM Stage at Diagnosis	I	27 (22.5%)
	II	36 (30.0%)
	III	26 (21.7%)
	IV	31 (25.8%)
Tumor Grade	High	26 (21.7%)
	Low	28 (23.3%)
	Moderate	66 (55.0%)
NI-RADS for Primary Site	NI-RADS 1	45 (37.5%)
	NI-RADS 2a	15 (12.5%)
	NI-RADS 2b	19 (15.8%)
	NI-RADS 3	29 (24.2%)
	NI-RADS 4	12 (10.0%)
NI-RADS for Lymph Nodes	NI-RADS 1	73 (60.8%)
	NI-RADS 2	21 (17.5%)
	NI-RADS 3	19 (15.8%)
	NI-RADS 4	7(5.8%)

TNM: Tumor, Node, and Metastasis, NI-RADS: Neck Imaging Reporting and Data System.

MRI evaluation of the primary tumor site revealed a range of imaging characteristics associated with NI-RADS scores. Among 20 patients classified as NI-RADS 1, no nodules or masses were detected, while 16 patients exhibited linear submucosal edema with high signal intensity (SI) on T2 and STIR sequences but no diffusion restriction or enhancement. Additionally, 7 patients had ill-defined non-mass low SI lesions indicative of fibrosis, and 2 patients presented with soft tissue distortion suggestive of inflammation or edema, both without diffusion restriction. NI-RADS 2a cases (n=15) displayed focal non-mass-like mucosal lesions with mild enhancement, while NI-RADS 2b cases (n=19) exhibited ill-defined soft tissue lesions with intermediate enhancement. Notably, well-defined nodules or soft tissue masses were seen in 29 patients, categorized as NI-RADS 3 and in 12 patients, who were classified as NI-RADS 4, demonstrating intense enhancement **(Table.2).**

Table 2. MRI finding for Primary site of studied patients

MRI Feature	T1	T2	STIR	DWI	Enhancement	No.	NI-RADS Score
No nodules or masses	--	--	--	--	--	20	1
Linear submucosal edema	Low	High	High	No diffusion restriction	No	16	1
Ill-defined non-mass low SI (fibrosis)	Low	Low	Low	No	No	7	1
Soft tissue distortion (inflammation/edema)	Low	High	High	No	Mild	2	1
Focal non-mass-like mucosal lesion	Low	High	High	Yes	Mild	15	2a
Ill-defined soft tissue	Low	Intermediate	High	Yes	Intermediate	19	2b
Well-defined nodule or soft tissue mass	Low	Heterogeneous	High	Yes	Intense	29	3
						12	4

MRI: magnetic resonance imaging, DWI: diffusion-weighted imaging, STIR: Short Tau Inversion Recovery.

MRI assessment of lymph nodes demonstrated a strong correlation between NI-RADS classification and nodal abnormalities. Among 40 patients classified as NI-RADS 1, no enlarged lymph nodes were detected, while 33 patients had lymph nodes without abnormal morphology, showing intermediate SI on T2 and high SI on STIR without diffusion restriction or enhancement. NI-RADS 2 cases (n=21) included lymph nodes with mild abnormalities, displaying heterogeneous enhancement but no diffusion restriction. In contrast, 19 patients classified as NI-RADS 3 and 7 patients categorized as NI-RADS 4 had lymph nodes with significantly abnormal morphology, characterized by intense enhancement and diffusion restriction **(Table.3).**

Table 3. MRI finding for Lymph nodes of studied patients

Lymph nodes	T1	T2	STIR	DWI	enhancement	No.	NIRADS
No enlarged lymph nodes	---	---	---	---	----	40	1
lymph nodes without abnormal morphology	Low	Intermediate	High	No	No	33	1
	Low	Intermediate	High	No	Heterogeneous	21	2
Lymph nodes with abnormal morphology	Low	Intermediate	High	Yes	Intense	19	3
						7	4

DWI: diffusion-weighted imaging, STIR: Short Tau Inversion Recovery.

(Table.4) presents recurrence rates based on NI-RADS categorization for primary sites and lymph nodes. It shows that higher recurrence rates are associated with higher NI-RADS categories, particularly in NI-RADS 2b, 3, and 4 for

primary sites and lymph nodes. For instance, NI-RADS 1 showed the lowest recurrence rates, while NI-RADS 4 exhibited the highest. All comparisons across categories showed statistically significant differences with a p-value of <0.001.

Table 4. Recurrence Rates Based on NI-RADS Categorization

NI-RADS Assessment	Category	No Recurrence	Recurrence	Recurrence rate (%)	P-value
Primary Site	NI-RADS 1	43	2	4.4	**<0.001***
	NI-RADS 2a	13	2	13.3	
	NI-RADS 2b	14	5	26.3	
	NI-RADS 3	8	21	72.4	
	NI-RADS 4	0	12	100	
Lymph Nodes	NI-RADS 1	71	2	2.7	**<0.001***
	NI-RADS 2	19	2	9.5	
	NI-RADS 3	5	14	73.7	
	NI-RADS 4	0	7	100	

NI-RADS: Neck Imaging Reporting and Data System. * Significant as P-value ≤ 0.05

Case 1: Male patient aged 76 years old, with cancer larynx under chemotherapy. (**Fig.1**). Case 2: Female patient aged 62 years old with tongue cancer underwent surgical excision of tongue mass with safety margin and modified radical neck dissection, with suspected recurrence. (**Fig.2**).

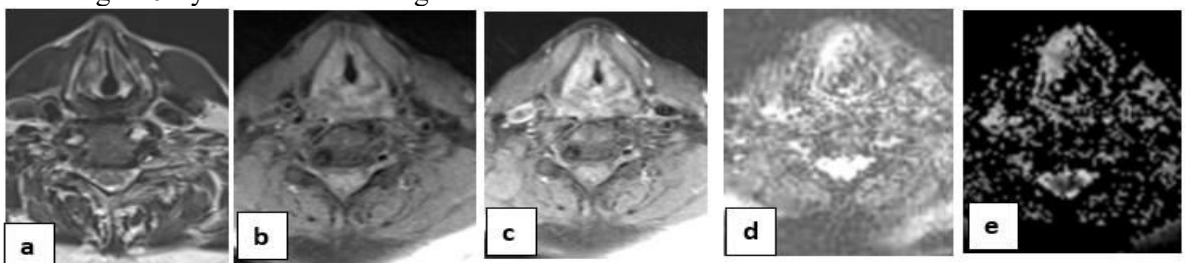
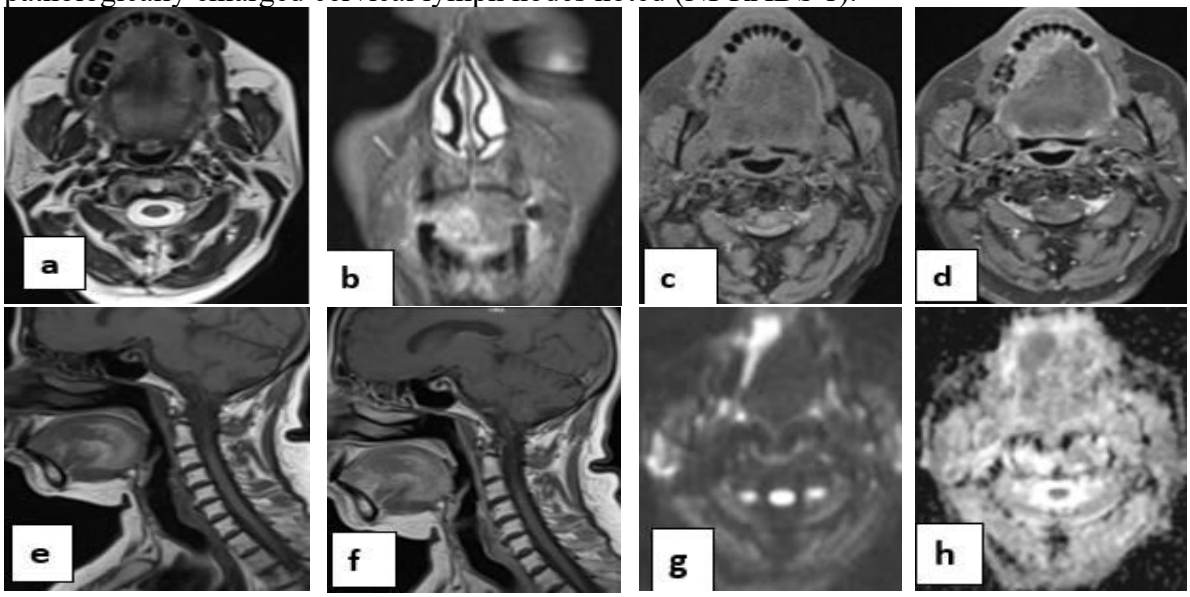


Fig.1. Axial T2WI (a) , Axial T1 pre and post contrast (b&c respectively) , axial diffusion WI and ADC map (d&e respectively) shows residual right transglottic mass measures 3.2 x1.7 cm in its axial dimensions, displaying heterogeneous T1 and T2 signal intensity with areas of diffusion restriction on DWI , it shows inhomogeneous contrast enhancement in post contrast series, The mass seen infiltrating the anterior commissure (NI-RADS 3). No pathologically enlarged cervical lymph nodes noted (NI-RADS 1).



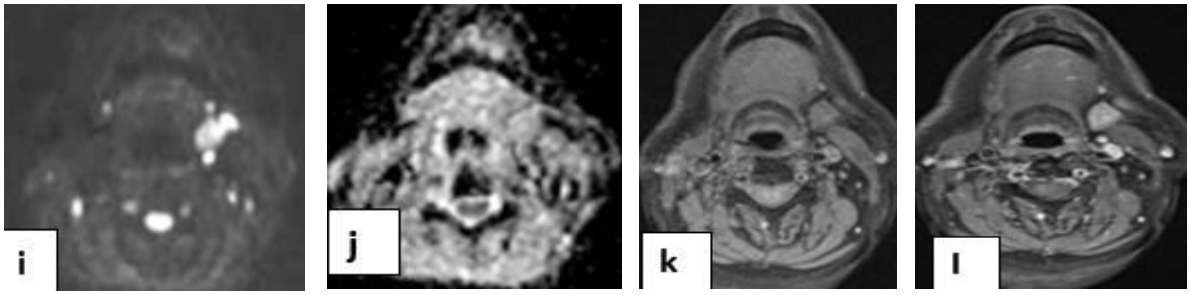


Fig. 2. Axial T2WI (a) , coronal STIR (b), axial pre and post contrast T1wI with fat suppression (c and d) , sagittal T1WI pre and post contrast (e and f) and diffusion WI and ADC map (g and h) shows a well-defined operative bed soft tissue mass of abnormal signal intensity, displaying intermediate to high T1 and heterogeneous T2 signal intensity with diffusion restriction on DWI and heterogeneous enhancement in post contrast series , it measures about 3.7x1.4x1.5 cm (NI-RADS III). Diffusion WI and ADC map (I and j) and axial pre and post T1WI with fat suppression (k and l) show left submandibular and upper deep cervical lymph nodes showing diffusion restriction on DWI and enhancement in post contrast series (NI-RADS 2).

Case 3: Male patient aged 56 years old diagnosed as nasopharyngeal carcinoma underwent surgical removal under regular follow up, (**Fig.3**).

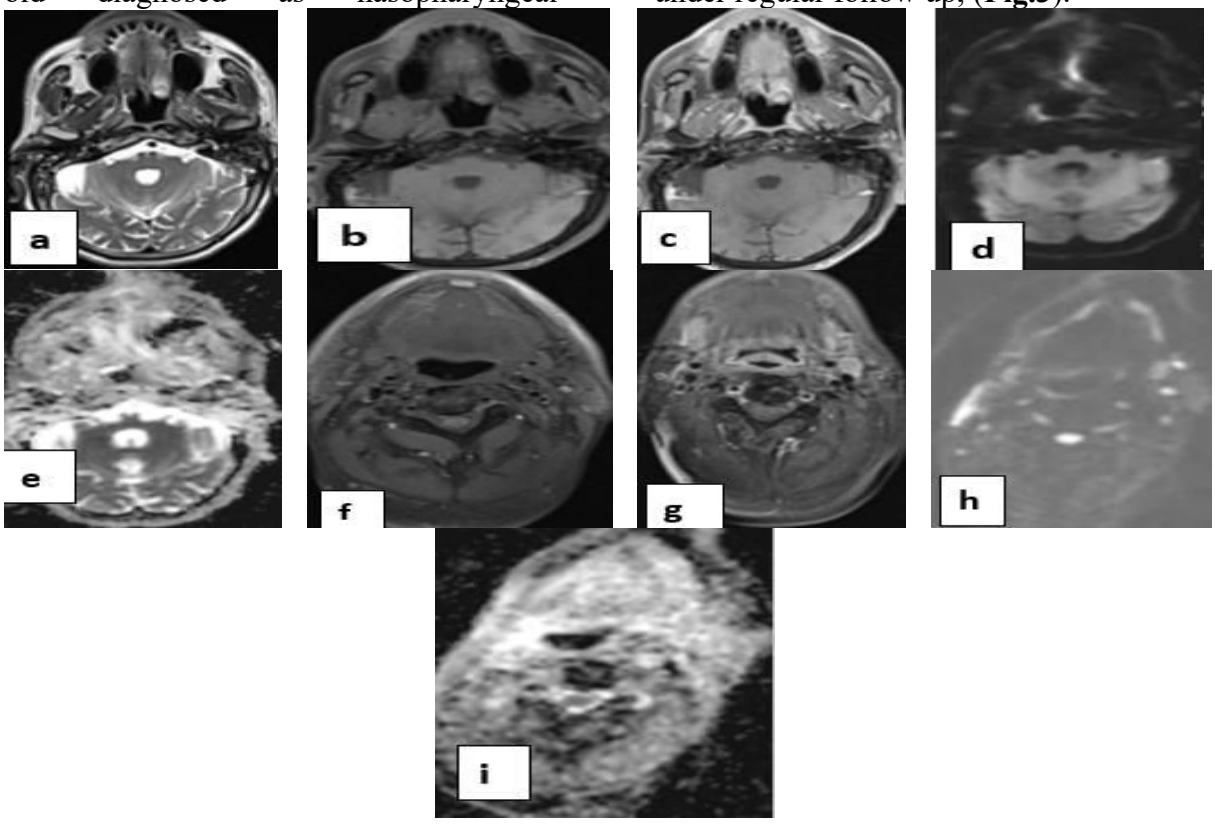


Fig.3. Axial T2WI (a) , axial T1WI with fat suppression pre and post contrast (b&c) , axial diffusion WI and ADC map (d&e) show no evidence of abnormal soft tissue thickening at nasopharynx , or areas of abnormal signal intensity , diffusion restriction or contrast enhancement (NI-RADS 1). Axial pre and post contrast T1WI with fat suppression (f&g) and diffusion WI and ADC map (h&i) show Few cervical lymph nodes displaying low T1 signal intensity with diffusion restriction and post contrast enhancement (NI-RADS II).

Discussion

Head and neck squamous cell carcinoma (HNSCC) is a complex malignancy characterized by high rates of recurrence, necessitating effective post-treatment surveillance to improve patient outcomes **(Hsu et al., 2019)**. The NI-RADS provides a standardized method for assessing the risk of recurrence based on imaging findings **(Johansson et al., 2022)**. In our study, we applied the NI-RADS system to evaluate recurrence rates and found a strong correlation between higher NI-RADS scores and disease recurrence, highlighting the utility of this tool in identifying patients at elevated risk.

In our study, the average age of participants was 59 years, with 80.8% of patients being male. This is similar to findings from Leoncini et al. **(Leoncini et al., 2018)**, who conducted a multicenter study with a median patient age of 59 and found a male predominance of 76% in their cohort of 4005 head and neck cancer (HNC) patients.

Regarding tumor sites, the most common primary site in our study was the larynx (29.2%), which aligns with findings by Imbimbo et al.**(Imbimbo et al., 2019)** who found laryngeal cancer to be the most frequent primary tumor site in their cohort of 326 patients, with 28.4% of cases involving the larynx.

The findings of this study underscore the predictive utility of the Neck Imaging Reporting and Data System (NI-RADS) MRI in detecting recurrent head and neck carcinoma post-treatment. The strong correlation between higher NI-RADS categories and recurrence rates suggests that NI-RADS serves as a reliable stratification tool for post-therapeutic surveillance.

The study demonstrated that patients classified as NI-RADS 1 exhibited the lowest recurrence rates, reinforcing its designation as a low-risk category. In contrast, NI-RADS 3 and NI-RADS 4 were strongly associated with recurrence, with NI-RADS 4 exhibiting the highest recurrence rates.

Furthermore, MRI characteristics within each NI-RADS category highlighted key imaging hallmarks indicative of recurrent malignancy. NI-RADS 1 cases predominantly exhibited benign post-treatment changes such as fibrosis and edema, while NI-RADS 2b and higher categories frequently demonstrated suspicious morphological features, including nodular enhancement and diffusion restriction. The distribution of lymph node NI-RADS categories mirrored primary site findings, with NI-RADS 3 and 4 lymph nodes showing marked enhancement and diffusion restriction, further reinforcing their malignancy risk.

These findings align with prior research on NI-RADS and imaging-based head and neck cancer surveillance. Aiken et al.**(Aiken et al., 2016)** first introduced NI-RADS as a structured reporting tool and demonstrated its ability to stratify recurrence risk effectively.

Several studies have explored the correlation between NI-RADS categories and recurrence rates. Hsu et al.**(Hsu et al., 2021)** demonstrated that NI-RADS 3 and 4 lesions have a high positive predictive value (PPV) for recurrence, with NI-RADS 4 lesions showing over 80% recurrence rates. Similar to our findings, their study emphasized that NI-RADS 1 and 2a categories were associated with low recurrence rates, supporting the role of MRI in safe surveillance strategies.

A comparative study by Hagiwara et al.**(Hagiwara et al., 2023)** investigated the role of NI-RADS MRI versus dynamic contrast-enhanced MRI (DCE-MRI) and concluded that combining NI-RADS scoring with perfusion imaging further improved specificity in detecting recurrence. Additionally, Baba et al.**(Baba et al., 2023)** found that adding apparent diffusion coefficient (ADC) values to NI-RADS classification provided enhanced differentiation between post-treatment

inflammation and recurrent tumors, a finding that could refine future imaging protocols.

In a multi-institutional study by Chowdhury et al.**(Chowdhury et al., 2024)**, NI-RADS-based MRI assessment was compared with PET-CT in post-treatment surveillance. The study found that NI-RADS 3 and 4 cases showed equivalent accuracy to PET-CT in detecting recurrence, further establishing MRI as a non-invasive yet highly effective modality. However, the study noted slight discrepancies in NI-RADS 2b cases, where PET-CT exhibited slightly higher sensitivity in detecting early microscopic disease progression.

Moreover, longitudinal studies by Kuno et al.**(Paleri et al., 2024)** have suggested that incorporating diffusion-weighted imaging (DWI) with NI-RADS assessment enhances diagnostic precision, especially in distinguishing treatment-related changes from true recurrence. This reinforces the need for advanced MRI protocols to optimize NI-RADS classification and improve diagnostic accuracy.

A meta-analysis by Baguley et al.**(Baguley et al., 2024)** compared the predictive performance of NI-RADS MRI with other imaging modalities and found that NI-RADS demonstrated a pooled sensitivity of 89% and specificity of 92% in detecting recurrence, comparable to PET-CT. However, they noted that interobserver variability remains a challenge, with some discrepancies in classifying borderline cases.

While most studies corroborate the predictive value of NI-RADS, some variations exist in recurrence rates, particularly for intermediate-risk lesions (NI-RADS 2b). Factors such as imaging protocol differences, patient selection bias, and variations in treatment regimens may contribute to these discrepancies. Further research is needed to refine the classification criteria for ambiguous cases and enhance the specificity of NI-RADS-based assessments.

The results of this study carry significant clinical implications. By confirming the predictive value of NI-RADS MRI, clinicians can optimize post-treatment surveillance strategies, reducing unnecessary biopsies and interventions for low-risk cases while ensuring closer monitoring for high-risk patients. The findings suggest that patients classified as NI-RADS 1 may safely undergo less frequent follow-ups, whereas those with NI-RADS 3 or 4 findings should undergo immediate further evaluation, including biopsy or PET-CT imaging.

This study also supports the role of NI-RADS MRI in early recurrence detection, which can improve survival outcomes through timely intervention. Notably, the integration of NI-RADS into routine imaging workflows can enhance multidisciplinary decision-making and patient management in head and neck oncology.

The study has some limitations, including a small sample size. Interobserver variability in NI-RADS interpretation, influenced by radiologist expertise, remains a concern. Additionally, imaging limitations, such as resolution variability and artifacts post-radiotherapy, should be addressed to enhance the clinical utility of NI-RADS.

Conclusion

This study emphasizes the usefulness of NI-RADS MRI in monitoring head and neck cancer recurrence. Higher NI-RADS scores correlated with increased recurrence rates, particularly for primary sites and lymph nodes. MRI characteristics such as tissue enhancement and diffusion restrictions support their role in detecting recurrence. NI-RADS MRI proves to be a valuable tool for risk stratification, aiding clinical decision-making.

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